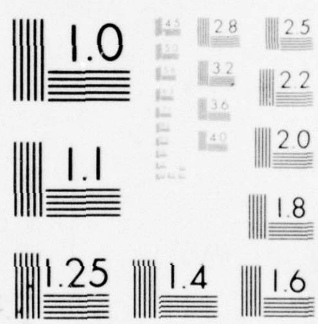

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William C. Mann

Man-Machine Communication Research: Final Report

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20. ABSTRACT

This is the final report of a multifaceted research and development effort in man-machine communication. The general goal of the program is to facilitate existing and future man-machine communication in areas of high military impact, including rapidly expanding use of on-line computing in communications and command and control. Highlights of the accomplishments of this research include:

* identification of major causes of man-machine communication difficulty for the computer-naive,'
* discovery of major communication strucures in human communication that have been left out of man-machine communication,'
* creation of a process model that exhibits these structures in a form which can be imitated directly in creating new man-machine communication processes,'
* creation of a new overview of how human communication functions in cooperative task-oriented activity,' and
* assistance in ARPA policy formation on CAI equipment development.

The research tasks of the program include:

DIALOGUE PROCESS MODELING - an effort to discover human communication methods which can be introduced into man-machine communication; this effort developed new methods for creating human communication models, new ways to extract the recurrent features of communication from examples, and a new form of process model for computer comprehension of human communication;

CAI TERMINAL NEEDS SURVEY - a survey of the computer terminal needs for military CAI of 1980, including an assessment of relative payoffs of equipment and software development options and a technical plan for meeting the needs with commercial equipment.

COMPUTER ASSISTED INSTRUCTION TELECONFERENCE - developing capabilities for on-line interaction between scattered CAI experts;

TERMINAL MODIFICATION - producing modification kits which make plasma terminals into general purpose terminals for use on the ARPANET;

HUMAN ERROR PERFORMANCE - supplementing knowledge of normal human communication with knowledge of partial communication abilities.

MAN-MACHINE COMMUNICATION RESEARCH: FINAL REPORT

by

William C. Mann

ISI/RR-77-57

February 1977

USC/Information Sciences Institute
4676 Admiralty Way
Marina Del Rey, California 90291

The research reported herein is supported by the Personnel and Training Research Programs of the Office of Naval Research (Code 458), Arlington VA 22217, Contract Authority Identification Number NR 154-374, Contract N00014-75-C-0710, under ARPA Order Number 2930 from the Cybernetics Technology Office of the Advanced Research Projects Agency. It is a continuation of the work of a previous contract, MDA903 74 C 0289 of Defense Supply Service - Washington under ARPA Order Number 2712. The report is approved for public release; distribution is unlimited. Reproduction in whole or in part is permitted for any purpose of the United States Government. Opinions expressed herein are those of the authors and do not necessarily reflect policy of any agency of the United States Government.

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This is the final report of a multifaceted research and development effort in man-machine communication. The general goal of the program is to facilitate existing and future man-machine communication in areas of high military impact, including rapidly expanding use of on-line computing in communications and command and control. Highlights of the program's accomplishments include:

- identification of major causes of man-machine communication difficulty for computer-naive people,
- discovery of major communication structures in human communication that have been left out of man-machine communication,
- creation of a process model that exhibits these structures in a form which can be imitated directly in creating new man-machine communication processes,
- creation of a new overview of how human communication functions in cooperative task-oriented activity,
- assistance in ARPA policy formation on CAI equipment development.

The research tasks of the program include:

DIALOGUE PROCESS MODELING - an effort to discover human communication methods which can be introduced into man-machine communication; this effort developed new case analysis methods for creating human communication models, new observer-based techniques which extract recurrent features of communication from natural examples, and a new workspace-oriented design of a process model for computer comprehension of human communication;

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ACKNOWLEDGMENTS

This research was performed by a multidisciplinary team. On the Dialogue Process Modeling task the team included James A. Levin and James A. Moore for the entire period, James H. Carlisle for the first half, and Robert Amsler, Armar A. Archbold, Timothy C. Diller, James Heringer, Paul Martin, Leroy C. Richardson and Robert Simmons for shorter intervals. Other tasks included work by F. Roy Carlson, Louis Gallenson, Thomas H. Martin and Monty C. Stanford for the duration of the tasks on which they have reported.

MAN-MACHINE COMMUNICATION RESEARCH: FINAL REPORT

OVERVIEW

Several very diverse aspects of man-machine communication were addressed by this work, ranging from fundamental research into how people actually communicate to development of equipment and tutorial methods so that particular people could quickly become able to use particular computer systems and programs. Part of the project focused on Computer-Aided Instruction (CAI), including a policy study comparing an investment in military CAI terminal development to various alternatives, and also preparation for a teleconference of CAI experts scattered across the country, communicating through the ARPANET. The remainder focused on the general difficulties of modern man-machine communication, and in particular on reducing its alien and bizarre appearance to computer users who are not computation specialists.

The work began in late 1974, taking up several CAI-related tasks which were already planned and in progress within ARPA. In early 1975, research was begun on what became the largest single task, creating a model of natural human communication which could serve as a guide and a source of corrective suggestions and processes to improve the sorry condition of man-machine communication as it existed (and still exists). All of the tasks except the Dialogue Process Modeling Task (and one small supplementary task) were completed in 1975.

The Dialogue Process Modeling Task was particularly productive of knowledge and opportunities. In addition to a process model of how people understand dialogue, it produced a new view of the nature of their communication. Judged in this view, modern man-machine communication schemes are missing some major parts; the model provides stereotypes for creating the right kinds of parts.

DIALOGUE PROCESS MODELING TASK

Task Goals -

The number of people who are using computers regularly in their military jobs is already large, and is rapidly increasing. Despite the diversity of systems and applications, there is a common pattern of difficulties in the man-machine communication required to use the computer systems effectively. Even the up-to-date timesharing systems are difficult for many people to use.

The pattern of difficulty typically includes these symptoms of communication problems:

- **Learning to use the system effectively takes a long time.**

- The system is "brittle," unable to function effectively with even minor variations in its human input.

- The system appears unnecessarily complex for its role.

- The system is unresponsive to the immediate needs of its users.

- Many details must be mastered by the users before the system becomes an effective tool.

- Communicating with the system has little continuity or sense of direction, making much repetition necessary.

- The user is not helped to decide what to do next or how to get the system to achieve particular purposes.

These might be considered to be simple design defects, but they have been around for a long time, they are found in the systems of all suppliers, and they have resisted serious efforts to relieve them through command language design and development of successive generations of interfaces. ***They are really symptoms of a much more profound problem.***

People communicate with each other using methods that have little to do with current man-machine communication methods. When they attempt to communicate with ***machines,*** their habitual methods fail or are severely restricted. Computer systems present an alien and bizarre appearance because their communication methods have never been properly reconciled to those of people. Based on this perception of the problem, the goal of the Dialogue Process Modeling Task was to create radical improvements in an actual man-machine communication application.* The goal was to be achieved in three steps:

1. Create a model of human communication, building it entirely out of computer processes.

2. Verify that the model could effectively interpret the kind of human communication it was intended for, identifying parts of the model exhibiting high success rates.

3. Implant these processes into the man-machine interface of an existing system, modifying them so that they perform the same functions in the new environment.

While these goals were adequate to guide the research, with hindsight they appear to be based on an underestimate of the systematic deficiencies of today's systems. The sorts of

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* An early report presenting this perception of the problem in detail (without the later research findings concerning use of goal knowledge) is found in ***Why Things Are So Bad for the Computer-Naive User*** by William C. Mann, ISI/RR-75-32, March 1975.

changes required to implant well-verified processes into modern interfaces are ***fundamental changes*** with ***pervasive effects***, comparable to the changes required to convert a simple stadium into a general-purpose public auditorium.

All of the task effort in fact went into the first of these three steps. This was due in part to the magnitude of what was found and in part to a decision by ARPA not to carry out the original three-year plan in its entirety. Thus ***the primary goal of the task was to create a process model of human communication.***

Specific Results -

On Model Performance Standards: At the beginning of the research there was an issue of what sorts of standards or benchmarks of performance would be appropriate for a new model. Existing practice in artificial intelligence was inadequate, and serious special issues were raised because the research was based on case analysis rather than the more traditional practice of building a system to perform some abstractly-specified function. There was a need to identify specific human-communication phenomena which were frequent, reliably identifiable, centrally involved in communication and independent of the task being performed by the communicators.

Over twenty phenomenon definitions were tried in the process of finding a suitable set. After considerable refinement and informal testing on naturally-occurring dialogues, six phenomena were defined in terms of judgment-procedures which people could employ to identify them. They were called Repeated Reference, Topic Structure, Requests, Similar Expressions, Expression of Comprehension and Correction Actions. For each of these, ***explicit instructions were prepared for an Observer to annotate dialogue for occurrences, including a number of judgments to be applied to each occurrence.*** These are found in ***Observation Methods for Human Dialogue***, by William C. Mann, James A. Moore, James A. Levin and James H. Carlisle, ISI/RR-75-33, June 1975.

These procedures are not specific to either the model which was built or the kind of text being annotated. They are suitable for judging and comparing a variety of models which claim to interpret natural language in agreement with the way people do. They are potentially useful as the basis of system benchmarks for a diversity of future systems which model human communication. All six phenomena are currently only weakly modeled in even the best of today's text- comprehension systems. There will be discernable degrees of success in modeling these phenomena for a long time to come.

These standards are designed to fit into a general system performance assessment method which was also developed as part of this project. It compares system behavior with corresponding human judgments, identifying agreements and disagreements. It is reported in ***Dialogue-Based Research in Man-Machine Communication***, William C. Mann, ISI/RR-75-41, November 1975.

On the Reliability of the Standards: After the phenomena were identified and suitably defined there remained an issue of whether they were reliably identifiable. Would annotations by an Observer be representative of widely shared responses to language, or would they be controversial and personal responses? If they were

idiosyncratic or difficult to find, then it would be unreasonable to evaluate models on their correspondence to human judgments of these phenomena. On the other hand, if these judgments were easy to make, and there was widespread agreement on the outcomes, then it is quite reasonable to require that a model which claims to interpret correctly should in particular have its interpretations correspond to these judgments.

In order to determine which was the case a reliability test of the observation methods was devised. This involved creating some new reliability measures for hierarchially structured nominal data, which is what the observation methods produce. These measures are somewhat novel in that they do not require that the items to be judged be identified before the test, nor do they require that there be an external absolute standard of what constitutes correct judgment. They are therefore suitable for these methods, in which the Observer selects what to annotate and all Observers are regarded as equally competent (and as competent as the test designers) at the task.

These measures were applied to a variety of dialogues drawn from two sources: the Apollo-13 spacecraft-to-ground communications and typed dialogues between computer operators and computer users on a timesharing system. ***The results in all of the five categories tested were that the Observers were achieving extremely high reliability, at least equivalent to having perfect agreement half of the time and 3-out-of-4 agreement the other half.*** This was surprising to some and gratifying to all, since content-based judgments of human communication have a generally poor reputation for reliability.

The results of these tests indicate that ***judgments on these phenomena represent shared, easily accessed knowledge about communication.***

These results were reported in ***An Assessment of Reliability of Dialogue-Annotation Instructions,*** by William C. Mann, James H. Carlisle, James A. Moore and James A. Levin, ISI/RR-77-54, January 1977. An issue remains of how much training in the techniques and categories of phenomena is needed before these levels of reliability can be achieved. The Observers used were the researchers who developed the methods, who were therefore highly trained. Subsequent research using other Observers will be needed to address this issue.

On Interpretation: Another major technical issue is identification of interactions between utterances in language interpretation. In dialogue the correct interpretation of almost every utterance depends on previous utterances by both parties. These dependencies have often been labeled "context," and there are many known ways to produce and demonstrate interactions, but there is no strong technical characterization of them at the level of detail of the phenomena considered in this research.

This research produced two results which help to characterize "context." First, the knowledge of what goals a speaker holds at the time when he creates his utterance has a central role in the interpretation of that utterance. The previous text may show recently acquired goals, or they may be long-standing ones. There is no limit to how far the evidence for a speaker's goals may be from the point where it is relied upon, and so no limit to the possible extent of this sort of "context." However, there need not be a great deal of this sort of information.

Second, there are ***important collections of goals and goal-pursuit information*** which recur frequently, are known to users of the language, and involve both parties in an essential way. These knowledge structures, which we have modeled using a construct called the Dialogue-game, are a source of a great deal of implicit communication and abbreviation. There is so much information conveyed implicitly by this particular mechanism that the later parts of a dialogue are often incomprehensible if this knowledge is not available to the interpreter. People consistently reveal some of their goals in dialogue, and they rely on the other party to recognize the goals and interpret whatever is said as motivated by those goals. The Dialogue-game knowledge structures are thus essential for both communicators in normal connected dialogue.

Identifying and characterizing these goal-regulated interpretation mechanisms is one of the ***major outcomes of this research.*** It is described in a project report, ***Dialogue-Games: Meta-Communication Structures for Natural Language Interaction,*** by James A. Levin and James A. Moore, ISI/RR-77-53, January 1977.

On Using the Knowledge: For any collection of knowledge about communication, whether it be new or old, there is the issue of what sort of interpretation scheme could possibly take it all into account correctly. In this research task this is a central issue, and it is addressed by designing a collection of processes which are jointly capable of performing interpretations of utterances in dialogue.

The result is called the Dialogue Model System. It consists of six autonomous interacting subsystems which use a common workspace for both their input and output. The content of the workspace represents the knowledge which one of the communicating parties is attending to. The changes in this workspace are the comprehension of the ongoing dialogue.

Two processors are devoted to inference, one to recognition of goal changes, one to interpretation of pronouns, one to bringing relevant new information from general long-term memory into attention, and one to bringing new external information into attention. They have been described in detail in ***A Goal-Oriented Model of Natural Language Interaction,*** by James A. Moore, James A. Levin and William C. Mann, ISI/RR-77-52, January 1977.

Several other short studies related to the Dialogue Model System were part of this project. They dealt with methods and content of model extensions, including methods for identifying and resolving references, representation of argument structure, match processing and model evaluation. They were reported in ***Working Papers in Dialogue Modeling, Volume 1,*** by James A. Levin and Armar A. Archbold, ISI/RR/77-55, January 1977, and ***Working Papers in Dialogue Modeling, Volume 2,*** by William C. Mann, Greg W. Scragg and Armar A. Archbold, ISI/RR-77-56, January 1977.

A New Characterization of Communication

Beyond these specific products the research has led to a ***new general view of communication*** which has strong implications for both man-machine and interpersonal communication. Communication has often been seen as simply message-sending. In that view the principal problem for the recipient is to "decode" the message, to somehow look up or construct its "meaning" in correspondence to its symbolic form.

That view has led to major emphasis on studying syntax, constructing grammars, defining the semantics of languages and on schemes for building a "meaning" for a sentence out of the "meanings" of its parts. It does not emphasize either the effects of using language or the comprehension of the relationships between sentences in connected text. This is the conventional view that in different forms dominates both man-machine communication research and natural language processing research.

In the new view, communication is pursuit of goals by the communicators. Some goals persist over many "messages" and influence their interpretation. There are simple and complex plans for communicating which are tacitly known to the communicators. These plans are used by the communicators to produce a large fraction of the total communication implicitly. The explicit "meaning" of the individual messages is only a small fraction of the total conveyed.

The communicator "makes sense" out of what he receives if and only if he fits it into a coherent knowledge of the sender's goals. This goal knowledge comes from two sources: the goals explicitly revealed by the sender and those goals which are parts of the communication plans which the parties share as tacitly known conventions. All of the communicator's knowledge of symbolic structure, including syntax, semantics and vocabulary knowledge, are parts of this goal-oriented interpretation scheme.

Interpreting what someone says is done projectively; it is a reconstruction of how he came to say it, with particular attention to why it was said and what purposes it tends to advance. The crucial information needed for this kind of interpretation relates means to ends, actions to results, and activities to the goals which they advance. Speaking or sending a message is seen as a particular action or set of actions. Initiating one of the conventional communication plans (such as the plan for soliciting help in performing a task) is likewise an action. Just as with physical actions, these actions make changes in relevant parts of the state of the world. Unlike physical actions, these must be recognized for what they are by the recipient to be effective.

Communication is seen as cooperative in a new way. Many of the frequently used plans require the active participation of both parties in order to succeed. Correcting errors, getting instructions, getting permission and asking for information all require both parties' active pursuit. There are conventional ways to do these things. They require engaging the other party in joint pursuit of a plan whose outline is known to both beforehand.

These are not merely added details or embellishments on a conventional view. Discovery that interpretation activities based on immediate goals are central in human dialogue opens up entirely new possibilities for the technologies and sciences concerned with communication with people. It makes possible the application of a great deal of existing research on problem solving, means-ends analysis, design and planning to the

understanding of human communication. It integrates the knowledge of language with the already developed knowledge of purposeful system behavior.

Future research based on this new characterization will lead to improved man-machine communication, especially for the computer-naive. The lack of continuity and sense of direction in today's machine interfaces, their excessive rigidity and their appearance of complexity all arise because the machine doesn't grasp the intent of what the person is doing. By adding to machine interfaces the knowledge of intended effects, many new kinds of processes which use this information can also be added. Help with method selection, relaxation of the need to "specify everything", immediately applicable machine-developed plans for using the machine are all made feasible when the machine knows *why* as well as how to do things. Specific recommendations for future research are included at the end of this report.

Major Deficiencies in Modern Man-Machine Communication

Given the understanding we now have of the large-scale factors which govern human communication, it is easy to see why man-machine communication could seem alien, highly restrictive, uncomprehending and awkward. It is so because ***the major regulation and interpretation structures are all missing.***

We compare human dialogue and typical man-machine communication practice for some of these features in Table 1 below. The table designates a "sender" and a "receiver" which should be identified with the person and the computer respectively in the man-machine communication case. (This puts the man-machine interface in the most favorable light, since typically the man-to-machine communication is schematized by parametric command languages, and the machine-to-man communication is not schematized at all.)

TABLE 1

	HUMAN DIALOGUE	MAN-MACHINE
SENDER'S GOALS KNOWN TO RECIPIENT	YES	NO
PARTICIPANTS CAN DECLARE GOALS AND COMMANDS	YES	NO
GOALS PERSIST OVER SEVERAL MESSAGES	YES	NO
GOALS IDENTIFIED WITH EACH MESSAGE	YES	NO
COMMUNICATION PLANS USED	YES	LITTLE
IMPLICIT COMMUNICATION TAKES PLACE	YES	LITTLE

Conventional man-machine communication can give the computer user a sense of always operating "out of context," of having to continually respecify what is relevant to performing a desired sequence of actions. In human communication it is the goal structures which carry the knowledge of what is relevant. Man-machine communication gives a sense of aimlessness, undirectedness, and lack of topic because there is no analogous body of knowledge being used to facilitate and interpret the communication.

Computer-naive users are especially hampered by these deficiencies in even the up-to-date systems. Since the military has a particularly strong stake in getting computer-naive users to use their systems, some specific recommendations for effective use of the new knowledge from this task appear at the end of this report.

CAI TERMINAL NEEDS SURVEY TASK

This task was a study of research and development alternatives in Computer-Assisted Instruction (CAI).

A policy study was conducted to assess the anticipated payoff of an investment by ARPA in the development of a new family of terminals for use by the military in Computer Assisted Instruction. Military and civilian experts in various phases of CAI interacted during four rounds of policy development activity using questionnaires and free-form written discussions. A guidance document for military decisionmakers was prepared, stressing the finding that an investment in the improvement and development of new forms of teaching software would have a higher payoff than design of a new family of computer terminals.

The survey was reported in ***A Policy Assessment of Priorities and Functional Needs for the Military Computer-Assisted Instruction Terminal*** by Thomas H. Martin, Monty C. Stanford, F. Roy Carlson and William C. Mann, ISI/RR-75-44, December 1975, prepared jointly by the USC Annenberg School of Communication and USC Information Sciences Institute.

Another part of this task had the goal of making as specific as possible the recommendations of the survey described above. Since the survey turned out favoring the currently forthcoming style of commercial terminals, this subtask concentrated on showing how these terminals could be made particularly useful and flexible in military CAI service. This included demonstrating that the major "special purpose" functional requirements of military CAI terminals could in fact be satisfied through the customization flexibilities found in terminals containing a microprocessor chip controller and buss communication between modules.

The results of this subtask were reported in ***An Approach to Providing a User Interface for Military Computer-Aided Instruction in 1980*** by Louis Gallenson, ISI/RR-75-43, November 1975.

COMPUTER-ASSISTED INSTRUCTION TASK

The major goal of this task was to facilitate interaction between various experts in CAI who were widely separated but addressing closely related problems. The facilitation was to be accomplished through a computer-mediated conference using a variant of an available teleconferencing program accessed through the ARPANET. The effort of this task included providing the communications facilities, computational resources, and necessary instruction in the use of the systems and programs involved.

The task was terminated by ARPA when it became clear that it could not be done in the economical and timely fashion originally envisioned, primarily because the terminal

modification kits required would be seriously late, and because of unforeseen equipment maintenance and communication expenses.

However, the task did develop methods for getting people to move quickly from unfamiliarity with the systems and programs involved into a self-sufficient competent state in which they could operate all of the system parts in a simple way and could acquire additional skills as needed without outside help. The methods use a combination of written documentation, personal introductory instruction and built-in help facilities within the programs to be used. These programs included the ZCONFER teleconferencing program (a modification of Forum-5), the XED editor and the MSG message processing system, all under the TENEX operating system on the ARPANET.

The key presentational device was a tutorial, documented in ***A Tutorial for Use of the TENEX Electronic Notebook-Conference (TEN-C) System on the ARPANET*** by James H. Carlisle, ISI/RR-75-38, August 1975.

TERMINAL MODIFICATION TASK

This task involved supporting and extending an ongoing ARPA effort to increase the flexibility of existing plasma terminals. Major goals included:

1. Making the plasma terminals capable of using the ARPANET without modifications to network conventions or programs.

2. Operating the plasma terminals on the PLATO system at the University of Illinois using the ARPANET as the communications medium (rather than the conventional dedicated lines).

3. Assessing the relative merits of the ARPANET and dedicated lines for this purpose.

Twelve Terminal Modification Kits were developed and documented by the University of California at Santa Barbara (UCSB) under subcontract, tested by ISI and delivered for use. The final UCSB report concludes that ARPANET communication is a viable option for these terminals only with a full mini-processor at the PLATO site. A full set of hardware and study documentation has been provided to ARPA in a set of working papers, and is also part of each of the Terminal Modification Kits.

HUMAN ERROR PERFORMANCE TASK

This task supplemented the Dialogue Process Modeling Task. It influenced the design of the Dialogue Model System at the system organization level. Its major goal was to discover patterns of communication which could be explained on the basis of a hypothetical three-step sequence:

1. A person has a collection of processes which, when they are all working properly, jointly support communication.

2. The person suffers a traumatic aphasia which disables some of his processes but not others.

3. The person exhibits an organized, stable partial communication capability.

This goal was pursued in an exploratory way through an informal cooperative arrangement with the Center for Communication Disorders of Los Angeles County Harbor General Hospital. Adult outpatients with various communication disorders were observed, and discussions were held with staff members on how the disorders might be represented in a systematic fashion.

The effort devoted to this task was very small, but sufficient to yield some useful observations which are reviewed below.

The amount of detail required in useful system design information greatly exceeds the amount of detail available in conventional diagnostic descriptions of adult aphasics. Furthermore, diagnostic descriptions and the associated theoretical works are not organized around processes or taxonomies of processes. It is therefore absolutely necessary for the researcher to deal directly with the phenomena of disturbed communication, since the available abstractions are inappropriate for his uses.

There is a general recognition on our part and on the part of aphasiologists and communication therapists that disturbed communication is more systematic, patternful and predictable in form than is captured by the present system of diagnostic descriptions. Because of the underlying diversity of phenomena, data on groups of patients, grouped according to general diagnostic description, may obscure important qualitative differences between individuals.

This sort of enterprise is dominated by problems of complexity, which arise in part from the fact that most patients have a combination of deficits rather than simple ones.

The most important and useful phenomena for communication modeling purposes are the defects of the fairly articulate, lightly damaged individual. The factors which make this sort of individual an ideal subject also make it very unlikely that he will be a clinical patient, even an outpatient. It would therefore be useful to work with individuals who have very simple deficits, who are, from the clinical point of view, fully recovered.

The most useful data for modeling are those which exhibit functional distinctness of similar capabilities. If a patient can perform action A but not similar action A', and another can perform A' but not A, then A and A' are seen to be functionally distinct despite their similarity. One of the serious challenges is to create reliable ways to make such determinations for various kinds of actions which are susceptible to disturbance.

RECOMMENDATIONS FOR FUTURE RESEARCH AND DEVELOPMENT

This research has created many new opportunities for improvement of man-machine communication and many new opportunities to increase our understanding of both man-machine and human communication. Our choices of top priority development activities and future research are described in the two sections below.

Recommendations for Application

How can the results of this research be used to benefit man-machine communication? Current practice in man-machine dialogue leaves out the principal mechanisms and kinds of interaction that regulate human dialogue. This is the source of many kinds of difficulty between people and computers, and constitutes a fundamental pervasive limitation on what can be achieved in interface design. The highest priority in man-machine communication research should be given to ***create an experimental system which performs goal-regulated communication with its users.***

This system should fulfill the following design constraints. It should:

1. be continuously aware of goals which each user is pursuing.

2. identify a particular goal with each requested action.

3. contain knowledge of plans (including both goals and actions) for performing the tasks.

4. contain knowledge of action-goal (means-ends) relationships for both machine actions and person actions, and be able to supply information about alternative ways to achieve goals.

5. be able to recognize and respond to satisfaction of goals and failure due to exhaustion of alternatives.

6. be able to impute the user's goals from his corresponding actions and action requests.

Such a system would be a major innovation, and it would contain the necessary prerequisites for helpful application of recent advances in the knowledge of planning.

The design of the interface and task-knowledge parts of the system should be generally patterned after the operation sequences of the Dialogue Model System. The control structure could borrow usefully from the Hearsay-II system, and the knowledge representation from Sacerdoti's Procedural Nets.

Recommendations for Future Research

The present research has revealed the profound contrast between the nature of human dialogue and that of current man-machine dialogue. It has identified important additions which can be made to man-machine systems, but the account so far is still sketchy and incomplete. We are impressed with the number of convenient tricks, abbreviation methods, approximate expression devices and other practices which we find in human communication. They are used with ease by everyone, and could profitably be imitated, but they have not yet been studied in a way that would make their structure clear and make imitation possible. The sort of case analysis employed in this research could profitably be extended in several ways. To benefit man-machine communication, these seem particularly important:

- More dialogue should be modeled. The scope should be expanded to include both peer dialogue and superior/subordinate dialogue. The latter has not been studied, but it is the closest human analogue to the current man-machine relationship. Part of the effort should be specifically directed at characterizing ***how a helpful subordinate or employee communicates.***

- The process description of the communicator as a problem solver should be developed in greater detail, with primary emphasis on operator identification and description.

- More detail is needed in several parts of the models. Reference resolution, use of hypotheticals, and control structure should especially be emphasized.

In addition to this research for man-machine communication, ***there should be an effort to model message interchange.*** A program specifically aimed at modeling formal record traffic in military message systems would eventually have a large payoff in automatic aid to high levels of authority in Command and Control. The research target should be a message analysis system which identifies messages which are relevant to the goals of an ongoing crisis.

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